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Design of compact reconfigurable UWB antenna with WiMAX and WLAN band rejection

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ABSTRACT

Two reconfigurable UWB antennas with band rejection characteristics are presented in this paper. By applying concept of parasitic element and etching slot in these two proposed antenna design WiMAX and WLAN band rejection are obtained, respectively to avoid potential electromagnetic interference (EMI). The proposed antennas are printed on 30mm x 40 mm Rogers5880 substrate. Furthermore, ideal switches are employed to achieve switchable band rejection UWB antenna. In this paper, two designs of reconfigurable UWB antenna with band rejection were proposed; namely a reconfigurable UWB antenna with WiMAX band rejection (Antenna 1), reconfigurable UWB antenna with WLAN band rejection (Antenna 2). The proposed antennas were successfully simulated, fabricated and measured. The Antenna 1 have impedance bandwidth from 2.99 GHz to 10.58 GHz with band rejection at 3.52GHz by utilizing C-shaped parasitic stripline. Meanwhile, Antenna 2 achieved an operating bandwidth from 2.99 – 10.82GHz with VSWR less than 2 except for the WLAN band operating at 4.92 – 5.84 GHz. The measured results for both antennas show good agreement with simulated ones.

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1. INTRODUCTION

Nowadays, modern telecommunication systems undergone rapidly progression development has increase the request for larger bandwidth features and high data rates transmission. In 2002 Federal Communication Commissions (FCC) has allocated 3.1-10.6 GHz frequency band for the commercial operation of ultra-wideband applications. Based on the FCC regulations, any systems that utilize the operating bandwidth of minimum 500 MHz or 20% from its center frequency can be employed in UWB systems. In February 2002, FCC approved the first rules and then make it official on the April 2002 which known as FCC, 2012 [1].

Since then, it is becoming increasingly difficult to ignore that UWB technology become one of the promising technology to fulfill the demand on providing wide bandwidth and high data transmission in the latest and future portable home and office devices for audio and video streaming [2-3]. Developments in the field of UWB have been led to competitive study between numerous company, government agencies and academic institution in order to exploit these technologies fully [4-7]. With the allocation of 7.5 GHz operating bandwidth researcher have shown an increased interest in UWB applications especially in imaging and positioning system, radar network and ground penetrating surveillance system and wireless communication. Therefore, the researcher will focus on these three aspects in designing antenna, which can influence the antenna performance as well as the whole UWB system. Planar monopole antenna is one of the most widely used antennas in wireless communication because of its light weight, easy to fabricate and low production cost characteristic [5].

To achieve a good performance of UWB systems, antenna needs to be compact in size, achieve nearly omni-directional radiation pattern and be able to minimizing interference [8]. UWB communication system needs to avoid electromagnetic interference (EMI) with the existing narrowband systems such as Worldwide Interoperability for Microwave Access (WiMAX) working at frequency band of 3.3-3.7 GHz and Wireless Local Area Networks (WLAN) working at frequency band of 5.15-5.85 GHz [8-13]. The existence of these inference will affect and degrading the performance of the overall UWB system. Therefore UWB antenna with bandstop element needs to be implemented to mitigate the interference. One of the most methods used to introduce band-rejection characteristics are by etching or embedding the slot in the radiator, ground plane or feedline. Surface current are intense and confined around the area of radiating patch and ground plane, feedline edge and area between radiating patch and feedline. Therefore, to make rejection of the narrowband more effective, the slot should be etched near these areas to trap more currents. There are various shapes and size of slot like U-shaped, V-shaped and H-shapes have reported by previous work [13-17]. A number of researcher have been reported using split ring resonator (SRR) and complementary SRR (CSRR) to filter out the interfering band [18-22]. SRR is formed by pairing a concentric annular or rectangular ring with split at the opposite end. The resonant frequency and bandwidth of the rejected band are dependent to the total length and width of the rings.

Another approach that can be used to suppress the interference from the nearby narrowband communication system is by placing the parasitic strip around feedline, radiator and ground plane [19]. Parasitic strip can be employed as a bandstop filter that will be blocked radiation at particular frequency [23]. The UWB antennas with tuneable band rejection are adapted to satisfy on-demand band rejection characteristics for smart communication systems. Reconfigurable stopband are frequently required when the need of the band-rejection narrowband communication system to eliminate the interference are changes Two switches are integrated into the band rejection element to achieved frequency reconfigurability [7, 24].

This paper is concentrated on developing two reconfigurable band rejection UWB antenna which capable to mitigate interference from the narrowband system that operate within UWB operating frequency spectrum from 3.1-10.6 GHz. The narrowband band rejection was achieved by introducing the bandstop element in the UWB antenna structure, namely C-shaped parasitic stripline and inverted U-shaped slot for WiMAX and WLAN systems, respectively.

2. ANTENNA CONFIGURATION

The geometry of the proposed UWB antenna with WiMAX and WLAN band-rejection characteristics is depicted in Figure 1(a) and Figure 1(b), respectively. The radiating patch, feedline and C-shaped parasitic stripline were formed from copper traces with thickness of 0.003mm were printed on the upper side of 0.787mm thick Rogers substrate with dielectric constant of 2.2 and loss tangent 0.0009. On the bottom side of the substrate, modified ground plane with dimension of 16 x 40 mm2 were printed also from copper. The overall dimension of the proposed antenna is 30 x 40 x 0.787 mm3.

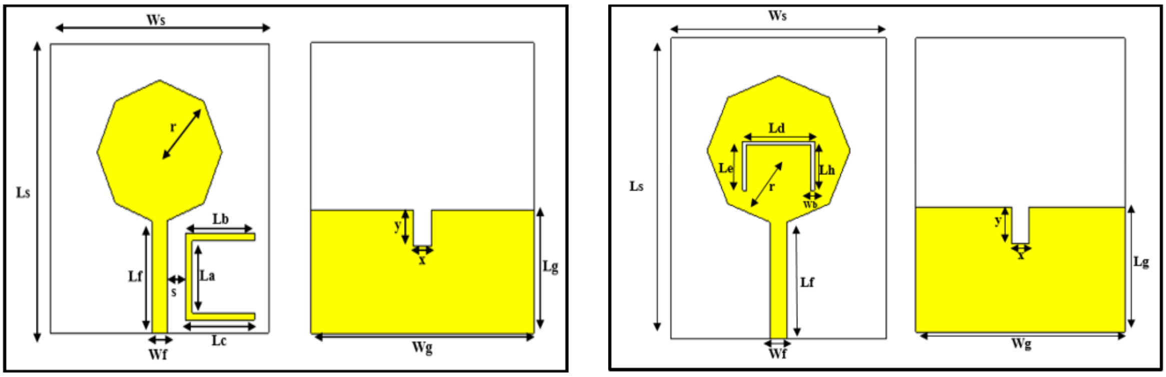
As illustrated in **Error! Reference source not found.**1(a), the λ/4 C-shaped parasitic stripline are placed beside the feeding mechanism to achieve desired stopband at 3.5 GHz. The C-shaped parasitic stripline with total length, Lps and width, Wa is located on the right sight of the feeding line. The switch are made up from a copper patch are embedded between parasitic stripline to control the total length of electric length either lengthen or shorten causing the frequency band-rejection for the Antenna 1.

By etching off λ/2 slot from radiating patch, band-rejection characteristics at desired frequency i.e. 5.5GHz can be realized as shown in Figure 1(b). This method is chosen due to the simple structure, effective, inexpensive and easy to fabricate. Meanwhile, an ideal switch is added at the inverted U-shaped slot at the Antenna 2 to realized reconfigurability of the band-rejection. During ON mode there is connectivity through the slot, meanwhile during OFF mode there is no connectivity through the slot.

Parameter and optimize dimensions of the UWB antenna with WiMAX band-rejection were summarized in Table 1. The proposed antenna design is designed and simulated using CST Microwave Studio Software.

Figure 2 shows the prototype of UWB antenna with C-shaped parasitic stripline with overall dimension of 30 x 40 mm2. Ideal switch are represented as the copper patch. Copper patch are present during the ON mode for antenna ideally to generate WiMAX band-rejection and the absence of copper patch are represent OFF mode for UWB antenna operate in whole UWB frequency range that all by FCC.

Prototypes of UWB antenna with inverted U-shaped slot during ON and OFF condition with overall dimension of 30mm x 40mm for experimental measurement were depicted in Figure 3. The proposed antenna are functioned in WLAN band-rejection UWB antenna during OFF condition and during the OFF condition are function in full cover UWB operating frequency.

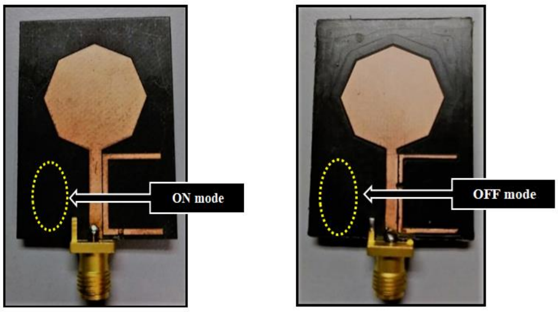


(a) (b)

Figure 1. The geometry of the proposed UWB antenna with WiMAX (Antenna 1) and WLAN (Antenna 2) band-rejection characteristics

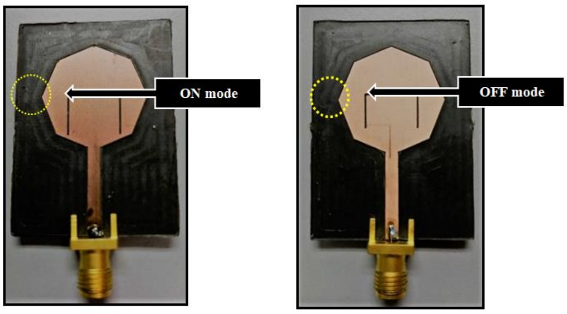
Table 1. Parameter and Optimize Dimensions of Proposed Antenna

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
h_s	0.787	s	0.2
L_a	10	W_a	1
L_b	12	W_b	0.2
L_c	12	W_f	2.4
L_d	10	W_g	40
L_e	6	W_s	30
L_h	6	x	2.2
L_f	18	y	3
L_g	16	s	0.2
L_s	40	W_a	1
r	10	W_b	0.2



(a) (b)

Figure 2. Antenna 1 Porotype during (a) ON mode (b) OFF mode



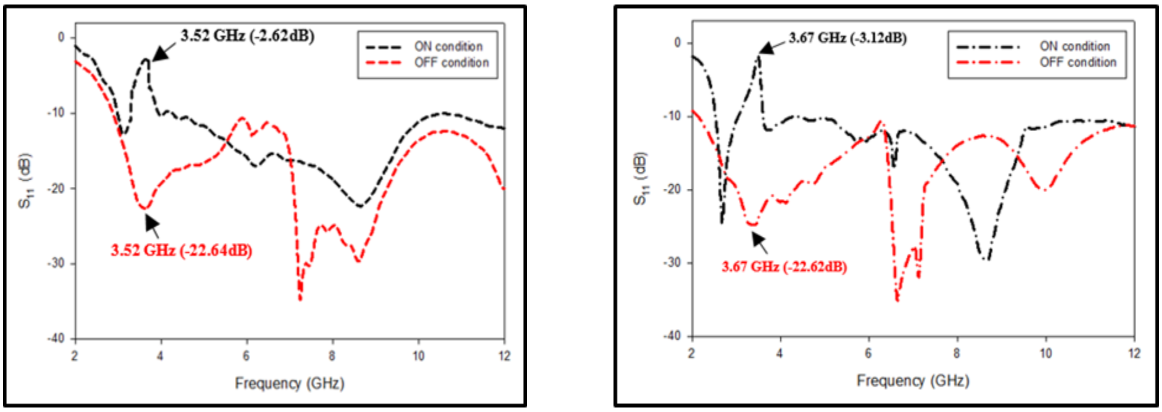
(a) (b)

Figure 3. Antenna 2 Porotype during (a) ON mode (b) OFF mode

3. RESULTS AND ANALYSIS

The fabrication and measurement of the antenna were carried out to verify the theoretical and simulated result. From Figure 4(a), we can observed that when the antenna is in the ON mode condition, the proposed UWB antenna can operated in ultra-wide frequency band of 2.99 GHz to 10.58GHz with WiMAX band-rejection are generated from 3.33GHz to 3.83 GHz. Meanwhile, when the switch is in the OFF condition antenna operated in the whole UWB band ranging from the 2.86-10.61GHz. The simulated reflection coefficient for rejected resonant frequency of 3.52GHz is equal to the -2.62dB and -22.64dB during ON and OFF condition respectively.

As presented in the graph Figure 4(b), it can be seen that the measured resonant frequency for rejected band during the ON condition is shifted 150MHz to higher frequency from the simulated result with the reflection coefficient value of -3.12dB at 3.67GHz. Meanwhile, for the UWB frequency band, the proposed antenna generates bandwidth around 7.50GHz to 9.20GHz during the ON mode and 7.70GHz to 9.29GHz during OFF mode.



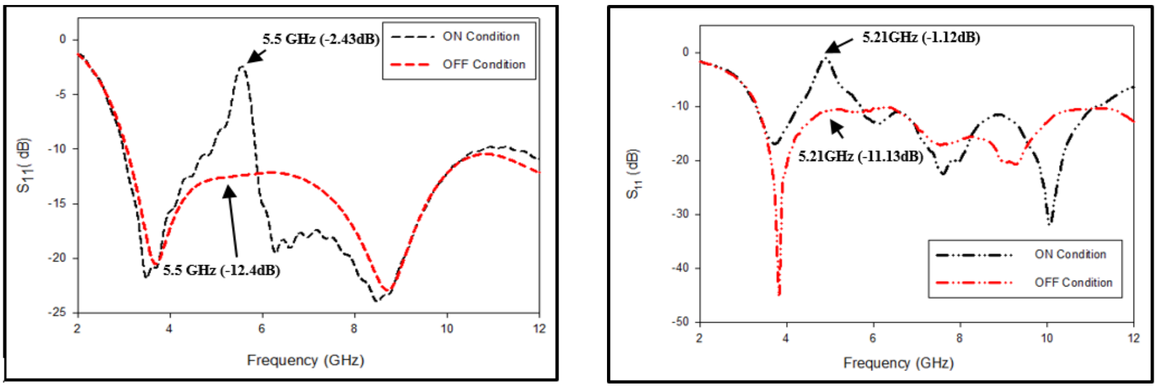
(a) (b)

Figure 4. S-Parameter of Antenna 1 between (a) Simulation and (b) Measurement during ON and OFF Condition

As illustrated in Figure 5(a) Antenna 2 are operated within 2.99-10.82 GHz frequency band which cover the entire UWB with additional WLAN rejected band. By activating resonating element the rejected band was generated from 4.92 to 5.84GHz. On the other hand, by configuring the switch into OFF mode, the antenna functioned in full cover UWB band without rejected band from 3.06-10.77 GHz with 111% fractional bandwidth. It can be seen at 5.5 GHz during ON condition S11 = -2.43dB and during OFF condition S11 = -12.43dB, which means that almost all signal are received are reflected back during ON condition.

The measured result of Antenna 2 during ON and OFF mode was depicted in Figure 5(b). As shown in the figure the resonant frequency of the WLAN band are shifted about 290 MHz to the lower frequency with S11 value of -1.12 dB. In addition for the UWB band, antenna are operated from 3.28 – 10.82 GHz and 3.34-11.42 GHz during ON and OFF condition respectively.

All these discrepancies between simulation and measurement were due to the irregular soldering of SMA connector and inaccuracy in the fabrication process. From the figure and table above, the measured and simulation result of UWB antenna with WiMAX band-rejection characteristics in terms of operating frequency, reflection coefficient and bandwidth are closely agree to each other although there is slight frequency shifting.

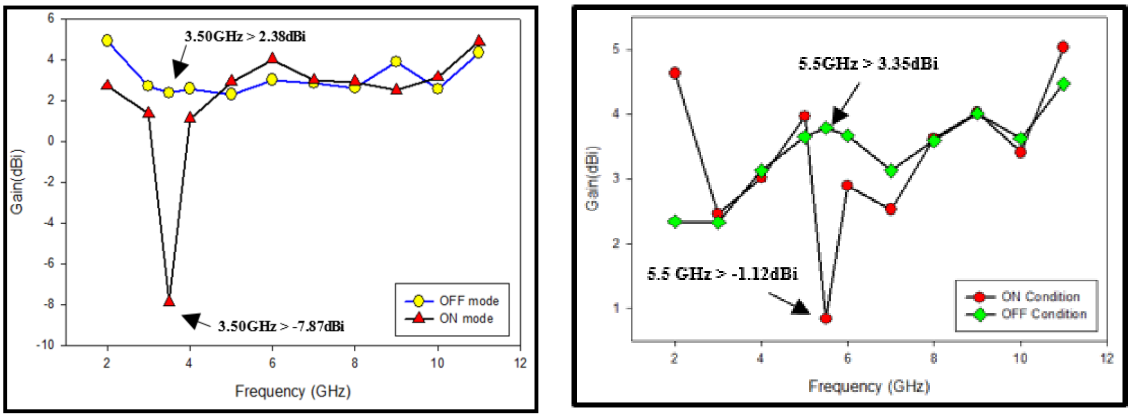


(a) (b)

Figure 5. S-Parameter of Antenna 2 between (a) Simulation and (b) Measurement during ON and OFF Condition

As illustrated in Figure 6(a) during ON mode, at the rejected frequency, 3.5 GHz the gain is equal to -7.87 dBi and for the operating UWB band are varied from the 1.10dBi to 4.90 dBi When the switch is in the OFF condition the proposed antenna are function in full cover UWB operating band and generate directivity gain from 2.30 dBi to 5.10 dBi.

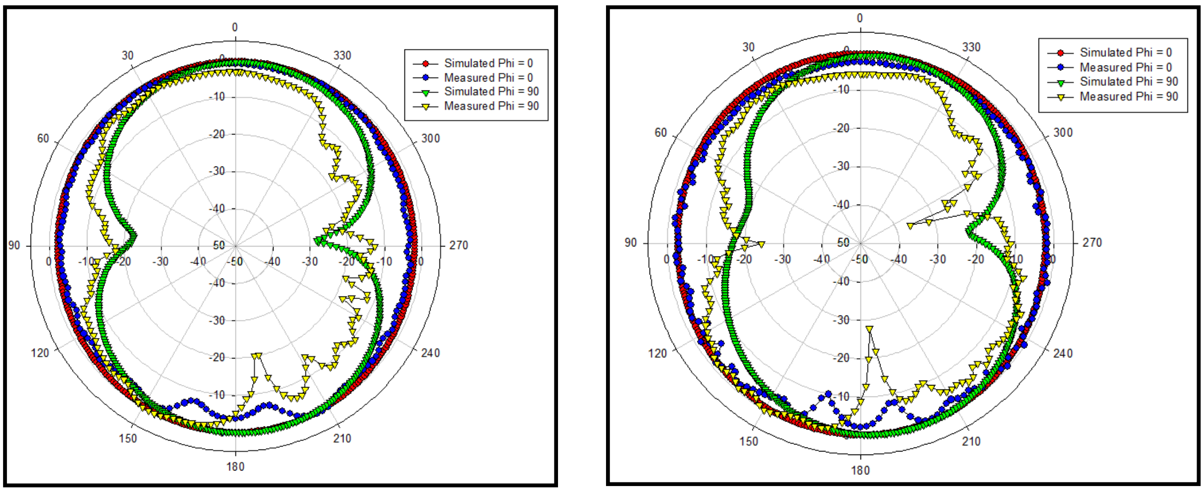
At resonant frequency of the WLAN band, 5.5GHz the gain is equal to -1.20 dBi during ON mode and the gain increased to 3.35 dBi during OFF mode as depicted in Figure 6(b). During ON mode it also can be observed that the gain are around 2.4 to 5.10 dBi over the entire UWB operating frequency excluding at the WLAN rejected band. The gain drop steeply at the 5.5 GHz shows that antenna are not radiated at that frequency. During OFF mode the peak gain generated over UWB operating frequency band from 2.3 to 4.50 dBi.



(a) (b)

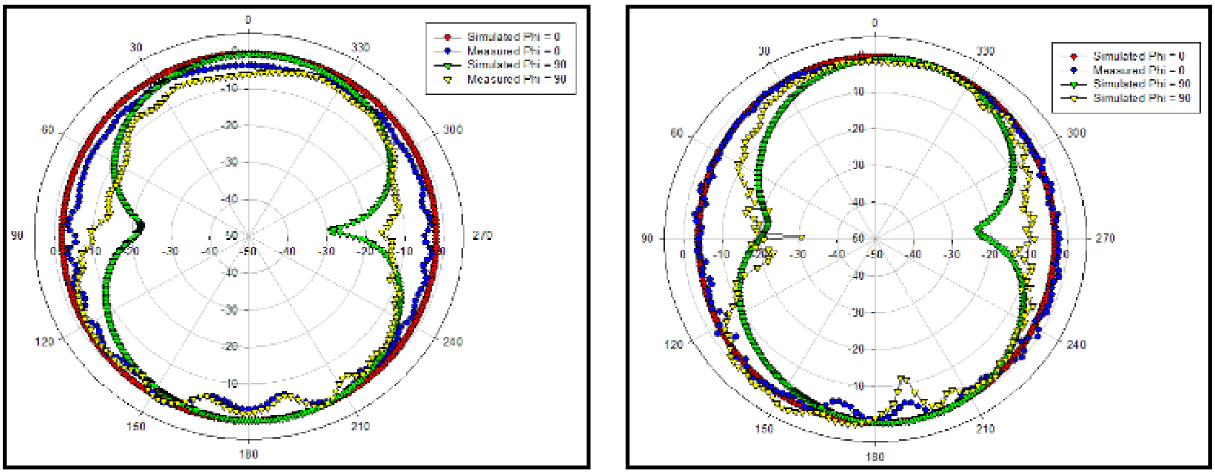
Figure 6. Simulated gain during ON mode and OFF mode (a) Antenna 1 (b) Antenna 2

To verify the accuracy of the simulation result, radiation pattern was done in the Anechoic Chamber at the ARC lab. The E-plane and H-plane radiation of Antenna 1 and Antenna 2 at the 6.85 GHz centre frequency of the UWB band during ON and OFF mode were displayed in the Figures 7 and 8, respectively. Proposed antenna display omni-directional pattern at H-plane and bidirectional radiation pattern at E-plane. The measured E-plane and H-plane are closely agreed with the simulated radiation pattern although there is slight shifting in the beam shifting. The shifting is due to the machining tolerance and measurement alignment.



(a) (b)

Figure 7. Simulation and Measurement Radiation Pattern of E-plane (Phi=90º) and H-plane (Phi=0º) during (a) ON and (b) OFF modes at 6.85 GHz



(a) (b)

Figure 8. Simulation and Measurement Radiation Pattern of E-plane (Phi=90º) and H-plane (Phi=0º) during (a) ON and (b) OFF modes at 6.85 GHz

4. CONCLUSION

The study described in this paper concentrated on the theory and design of an ultra-wideband antenna operated at the 3.1 to 10.6GHz frequency range with tunable WiMAX and WLAN band-rejection with the center frequency of 3.5GHz and 5.5GHz, respectively. Antenna 1 called reconfigurable UWB antenna with WiMAX band rejection. By integrating resonating element into the UWB antenna, the antenna operated from 2.99 to 10.58 GHz with WiMAX band rejection generated from 3.33-3.83 GHz. Antenna 2 called reconfigurable UWB antenna with WLAN band-rejection satisfied -10dB operating frequency band 2.99-10.82 GHz with WLAN band-rejection characteristics. The WLAN stopband from 4.92-5.84 GHz was introduced by an inverted U-shaped slot was etched off the radiating patch. Furthermore, an ideal switch has been added to the resonating element to control the activation of the rejection band. By configuring the switch, antenna can worked as single band rejection UWB antenna and a UWB antenna.Overall result shows a good agreement for both measured and simulated result.

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Nurfarahin binti Miswadi was born on 3rd July 1990 in Johor, Malaysia. After completed the foundation studies in Pusat Asasi Sains Universiti Malaya, she pursued her studies in Shah Alam, Malaysia. In 2013, she received the Bachelor of Electronic Engineering (Communication). Due to her high interest in research, she continued her Master studies in Electrical Engineering at the Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM). Her research interest include the studies of Radio Frequency (RF), antenna design and electromagnetic radiation analysis. She is a members of IEE Malaysia and now attached with Antenna Research Centre (ARC). She has published one journal articles and three conference paper on various topics related to reconfigurable UWB antenna. Besides, she has also given big contribution in other projects and become co-author for other conference papers.

Mohd Tarmizi Ali received the B.Eng. degree in electrical engineering from the Universiti Teknologi Mara (UiTM), Shah Alam, Malaysia, in 1996, the M.Sc. degree in electrical engineering from the University of Leeds, Leeds, U.K., in 2002, and the Ph.D. degree in electrical engineering from the Universiti Teknologi Malaysia (UTM), Johor, Malaysia, in 2010. He has been a Professor with the Faculty of Electrical Engineering (FKE), UiTM, and the Group Leader of the Antenna Research Centre (ARC), FKE UiTM, since 2011. He is a senior member for the IEEE and member for the Antenna Propagation/Microwave Theory and Technology/Electromagnetic Compatibility (AP/MTT/ECM) Joint Chapter. He has authored more than 100 journal papers and conferences proceedings on various topics related to antennas, microwaves, and electromagnetic radiation analysis. He has also filed five patent applications on communication antennas. His research interests include the areas of communication antenna design, radio astronomy antennas, satellite antennas, and electromagnetic radiation analysis. Dr. Tarmizi was the Chair and Technical Program Chair of the IEEE Symposium on Wireless Technology and Applications, between 2011 and 2012. He has been a very promising as a Researcher, with the achievement of several International Gold Medal Awards, a Best Invention in Telecommunication Award, and a Special Chancellor Award from UTM for his contribution to research and innovation and was the recipient of Postgraduate Best Student Award 2011 from UTM.